DEEP RIPPING EXPERIMENTS IN N-E SASKATCHEWAN

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(This work is supported by the Agriculture Development Fund)

INTRODUCTION

Crop growth on solonetzic soils is limited mainly by the condition of the B horizon. "The solonetzic B horizon is very hard when dry and swells to a sticky mass of very low permeability when wet" (Canada Soil Survey Committee, 1978). This horizon presents a physical limitation to the penetration of roots, water and air. Consequently, the shallower the depth to the B horizon, the shallower the zone for root proliferation and soil water storage. Chemically the solonetzic B horizons are separated from other B horizons by the fact that they must have a ratio of exchangeable Ca to Na of 10 or less (Canada Soil Survey Committee, 1978). Water soluble cations can also be used to differentiate solonetzic B horizons from chernozemic B horizons. Ballantyne and Clayton (1962) formulated the differentiating criteria after comparing chemical characteristics with morphological characteristics of 291 soil profiles, varying in degree of solonetzic development. Solonetzic soils would have greater than 50% water soluble Na in a soil layer above the C horizon, intergrades between 33 and 50%, and Chernozemic soils less than 33%. In terms of water soluble Ca/Na ratio the values they listed are: 0-0.5, 0.5-1.0, and >1.0, of solonetzic, intergrades, and chernozemic soils, respectively. There has also been a report of solonetzic soils where soluble Na contents are quite low (Ellis and Caldwell, 1955). These "magnesium solonetz" soils apparently have a narrow Ca/Mg ratio on the exchange sites.

The quality of the A horizon depends on the stage in the development of the solonetzic soil. In some of the worst cases the A horizons have little organic matter, crust easily and have an acid pH. Frequently, the C horizon contains considerable amounts of salts which limit water availability to plants. However, the type of salts present in the C horizon are usually Ca-salts, which are important with respect to the reclamation of these soils. The extent of solonetzic soils in Saskatchewan has been estimated at 1.5 million hectares (Ballantyne, 1982).

Deep tillage operations attempt to disrupt the B horizon and improve root and water penetration and subsequent leaching of salts. Deep plowing mixes the Na-rich Bnt horizon with the Ca-rich C horizon. The Na is then replaced by the Ca on the exchange sites in the soil, the highly soluble Na can then be leached with rainwater. In some cases, lime from the C horizon when mixed with the A horizon, can neutralize the acidity in the A horizon. Much of the deep plowing research in Western Canada has been done in Alberta (Cairns, 1961, 1962; Bowser and Cairns, 1967) . In Saskatchewan Ballantyne (1982) studied soil conditions and crop yields for 5 years following deep plowing of solonetzic soils near Radville. Deep plowing had increased topsoil levels of clay, fine clay, pH, $CaCO3$ and water soluble Ca. Water soluble Na was decreased. These changes persisted over a 5 year period. Average wheat yields following deep plowing were higher for all 5 years (Fig 1).

Deep ripping has been found to be less effective than deep plowing in reducing the exchangeable sodium percentage of solonetzic soils (Alubaidi and Webster, 1982). Deep ripping does affect soil physical parameters. Bole (1986) found increased surface infiltration and hydraulic conductivity 3.5 years following deep ripping in plots in Vauxhall, Alberta. Soluble Na and sodium adsorption ratio were lower in deep ripped plots. However, this effect only lasted for 2 years. Alubaidi and Webster (1982) found that deep ripping had resulted in increased leaching of salts. Information on crop yields following deep ripping is limited. Lavado and Cairns (1980) found that in one field wheat yields were increased, while in another field the yields were decreased. Apparently in the

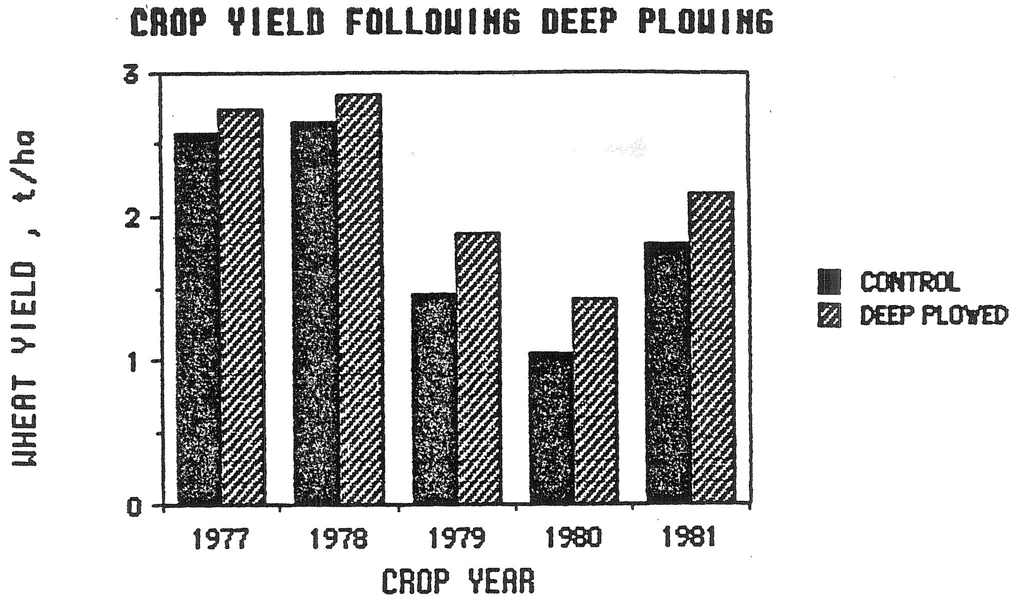

Fig. 1. Crop yields following deep plowing in 1976 (Ballantyne, 1982).

second field, ripping had resulted in deteriorated topsoil conditions in terms of reduced extractable Ca and increased extractable Na.

In the Tisdale region, farmers had noted yield increases on strips of land which had been ripped during the installation of power lines. Staff from the Saskatchewan Soil Survey Unit identified solonetzic profiles in a number of fields in this area. The objective of this study is to determine the feasibility of deep ripping in the northern grain belt.

MATERIALS AND METHODS

The sites are located north and east of Tisdale. The fields were surveyed by staff from Saskatchewan Soil Survey Unit and some of the soil profiles excavated showed morphological features common to solonetzic soils. Chemical characteristics of the fields are listed in Table 1. Water extractable cations were measured. Exchangeable cations and C.E.C. were estimated from water soluble cations and % saturation using the Gapon coefficient as described by van Beek et al. (1975). The fields were deep ripped in October

Table 1. Chemical characteristics of deep ripped fields.

Location (farm)	Depth (cm)	C.E.C.* me/100g	pH	E.C. mS/cm	S.A.R.	% Na H_2O sol.	Ca/Na H_2O sol.	Ca/Na* exchange
McEwen	0-15	32.6	5.7	0.4	0.8	24.8	1.69	14.5
	15-30	35.8	6.7	0.3	1.2	35.3	0.82	10.1
	30-60	42.6	8.0	0.6	2.2	44.4	0.54	7.9
	60-90	57.0	8.1	1.0	3.9	55.8	0.29	6.7
	90-120	65.2	7.9	3.6	3.2	26.6	1.15	11.9
Boxall	0-15	35.8	6.2	0.7	1.1	24.5	1.46	10.7
	15-30	24.4	7.2	0.4	1.6	39.9	0.64	4.2
	30-60	61.9	7.9	1.5	2.4	34.2	0.76	13.1
	60-90	73.3	7.9	5.9	4.9	30.2	0.92	11.2
	90-120	78.2	7.5	7.5	7.0	37.3	0.58	9.5
Morgan	0-15	35.8	5.9	0.9	2.9	48.6	0.51	4.3
	15-30	48.9	7.4	0.8	4.5	66.3	0.26	4.7
	30-60	65.2	8.1	1.8	7.7	70.5	0.17	4.8
	60-90	92.9	8.1	4.5	10.3	62.2	0.21	23.5
	90-120	104.3	8.0	6.6	9.9	51.7	0.36	

* Indicates estimated values

1985. A KELLO-BILT subsoiler was pulled with a 1150 VERSATILE tractor (450 h.p.), shanks were 61 cm apart and the depth setting was 75 cm. At each location ripping was carried out in strips 12 meters wide and 800 meters long. Soil conditions at the time of ripping were "dry". Following ripping, the fields were disced a number of times in order to smooth down the extreme surface roughness left by the ripping. During 1986, crop yields were monitored both with a square meter and with a weigh wagon. Soils were sampled in the fall of 1986 for moisture, bulk density and for detailed salinity analysis.

RESULTS AND DISCUSSION

According to the differentiating criteria set out by Ballantyne and Clayton (1962), the McEwen and Morgan sites represent solonetzic soils. At McEwen the B horizon contains 56% water-soluble Na at 60-90 cm depth and at Morgan both the A and the B horizons contain water-soluble Na equal to or exceeding 50%. These B horizons also satisfy the criteria for exchangeable Ca/Na ratios to be equal to or smaller than 10. The Boxall site appears to be less severely solonetzic and falls in the intergrade category, between chernozemic and solonetzic. Seasonal fluctuations in water soluble Na content must be taken into account when assessing water-extractable cations for soil analysis. Field seeding operations were done without making any special adjustments when the seeder traversed deep ripped strips. Consequently in the ripped strips seeding depth was often deeper than intended. This phenomena appeared to have resulted in delay of plant establishment at the Morgan site. This "set-back" in crop growth had disappeared by mid summer.

Yields at all three sites were higher in the ripped strips (Table 2). Morgan's barley yields were greater by 16% (7.7 bu/ac). Weigh wagon results indicated more conservative increases between 3.7 and 6.0 bu/a. Boxall's wheat yields were greater by 26% (8.7 bu/ac) and McEwen's peas yielded 45% more on tilled strips (604 lbs/ac). It must be pointed out that the north-east was quite "dry" for most of the 1986 growing season.

Table 2. Crop yields for 1986 deep ripping experiment.

Location	Tillage	Dry Matter kg/ha	Grain kg/ha	C.V.* %	Grade	Soil** Strength kg/cm^2	Soil Moisture %
			Barley				
Morgan	Control	5362 a	2558 a	21.6	1	75.8	17.4
	Ripped	6264 b	2972 b	19.6	1	47.2	21.3
			Wheat				
Boxall	Control	4262 a	2284 a	22.2	1	16.8	16.3
	Ripped	5795 b	2872 b	19.3	1	11.8	20.2
			Peas				
McEwen	Control	2899 a	1516 a	23.0	2	83.8	12.8
	Ripped	4217 b	2193 b	24.5	2	66.8	15.1

*Coefficient of variation

**Penetrometer reading at 7.5 cm

Values followed in columns by the same letter are not significantly different at the 5% level.

Consequently crops growing on deep ripped soils possibly suffered from less water stress than those growing on the non-ripped soils. There was considerable variability in crop yield along the 800 m transects, especially for the control. Soil strength, measured at the time of harvest was in each case lower in the ripped area. However, soil moisture conditions of the top 15 cm were also higher in the ripped areas. It is therefore difficult to assess the importance of the differences in soil strength.

Soil physical properties were measured during the fall of 1986. Soil bulk density appeared to be lower in the deep ripped plots, but differences were not significant (Table 3). At the Boxall site trenches were dug with the help of a backhoe, in order to expose complete soil profiles. This allowed for additional analysis of soil structure in terms of aggregate size distribution and field air permeability. Aggregates in the surface soil layers tended to be of smaller diameter in the deep ripped plots but differences were not significant. Air permeability tended to be greater in the top 30 cm in deep ripped plots, but values were not significantly different. One of the problems with analysis of soil structure in these soils is the extreme spatial variability resulting in very large variances. Monitoring of soil chemical characteristics over the next two years may reveal if leaching of Na-salts is occurring in deep ripped soils.

The deep ripping tillage work has been extended to now include paraplowing to a depth of 50 cm. Additional sites were established in the fall of 1986 at Arborfield, Cut Knife, Lucky Lake, Birsay and Glenside. The sites represent a range of soil textures from medium to heavy, as well as a range in solonetzic development. Crop and soil monitoring will continue for at least 2 more years.

Neutron tubes have been installed at 7 sites. These tubes allow for the measurement of soil moisture content to a depth of 120 cm, using a neutron probe. Furthermore, soil bulk density can be measured to the same depth with a gamma probe. A further 3 sites will receive neutron probes this spring. The above allows for measurement of soil moisture conditions and density at specific locations for the next two years. By returning to exactly

Table 3. Soil physical properties of field plots in the fall, 1986

Location	Depth (cm)	Control	Deep Ripped
		Bulk Density (gm/cm3)	
Morgan	25	1.40	1.21
	40	1.36	1.29
	60	1.32	1.32
	80	1.37	1.36
	100	1.40	1.40
	120	1.43	1.43
McEwen	25	1.24	1.25
	40	1.38	1.34
	60	1.37	1.35
	80	1.41	1.40
	100	1.44	1.47
	120	1.48	1.50
Boxall	25	1.30	1.22
	40	1.31	1.27
	60	1.35	1.33
	80	1.38	1.39
	100	1.43	1.42
	120	1.43	1.42
		Aggregate Size Distribution (mm)	
Boxall	0-15	10.88	6.69
	15-30	17.39	15.88
		Field Air permeability (*10-6 cm^2)	
Boxall	0-15	6.50	3.95
	15-30	1.18	3.84
	30-45	0.65	1.72
	45-60	0.59	0.38

the same location for the measurements for moisture and density at each sampling interval, sampling variability is reduced.

CONCLUSIONS

Solonetzic soils were identified in the Tisdale area. Deep ripping of these soils resulted in substantial yield increases in wheat, barley and peas. There was considerable variability in crop yield along 800 m transects, especially in the non-ripped parts of the fields. Analysis of soil physical properties revealed no significant trends attributable to deep ripping. The soils did tend to be less dense and more aerated following deep ripping. Additional field plots were established in the fall of 1986, at Arborfield, Cut Knife, Lucky Lake, Birsay and Glenside. A paraplow was used in a number of the field sites. At present 10 field sites are included in the study, these represent a range in soil texture, as well as in solonetzic development. Long-term monitoring of soil physical and chemical parameters over at least a 3 year period is required to fully evaluate the effectiveness of deep ripping in this region.

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